

Prevent Turtle Trap in the Fishing Gear Using Sound

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Abstract— Malaysian fishing regulation prohibits any fishing activities using gill net since it frequently caused turtles captured in the net. In Malaysia only, the number of turtle landings has been decreasing every year while regulation enforced to prevent turtle extinction had affected fisheries production. Since fishing is an important economic activity especially in east coast and east coast of Peninsular Malaysia, many fishermen still using gill net illegally to gain higher and cheaper production. Plenty of fish had been caught, but turtles trapped in fishing gear are another major problem. It is clear that prohibition is not an effective method. Thus, the proposed research will involve the development of a device based on the findings and integration of previous research. We have found the technical specifications to develop the Turtle Excluder Device that dispels the turtles but enable fish to be caught by gill net. It has successfully determined that turtles are sensitive to specific frequency and signals that can be used to dispel the turtle. In the same time, the transmitted signal does not have any effect to fish.

Keywords—Turtle; sound; excluder; fishing

I. Introduction

Sea turtles are important marine animals, not only under CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) agreement but also traditional living resources in the ASEAN region. Most of the ASEAN member countries have established national programs on the conservation and enhancement of sea turtles. However, information on research, conservation and enhancement of these animals in the region is rather fragmented. Fisheries (Prohibition of Fishing) Regulations 1990 released by Fisheries Department Malaysia prohibits unsustainable fishing practices gill net for catching stingray or skates fish at zone A or coastal marine (5 mile from coast line) of the sea. One reason for this prohibition is the incidental captured of the turtle in the net. Turtle and

stingray have the same habitat and when the turtle landed to reproduce and feed into the beach they would die in drawn out caused by catch in the net. This has caused decreasing number of landed turtle every year.

Green turtle (*Chelonia mydas*) is classified as endangered species, while the hawksbill turtle (*Eretmochelys imbricata*) and the leatherback-turtle (*Dermochelys coriacea*) are classified as critically endangered. Fisheries Regulation 1990 was aimed to prevent turtle extinction; however this regulation had caused stingray fish production to decrease dramatically. The stingray fish is a popular catch which is in line with the food industry demand. In addition, recreational and sport fishing stingray is also a point of interest for tourism industry. The stingray skin also has commercial values in exotic leather wear since it is very rare to found and have high value.

Meanwhile, the usage of gill net had been monitored by local authority since many fishermen still used it illegally. The Turtle and Marine Ecosystem Center (TUMEC) has reported that in 2006, they had confiscated more 20 gill nets during the inspection. Fishermen still using gill net in the zone A, which have a big population for stingray fish. One interesting point to note is that hook and long lines do not seem to be catching turtles within territorial waters, although they are known to take turtles in offshore areas. It is clear that prohibition is not an effective method.

II. Turtle and fish hearing threshold

Rogers and Triyett (2007) studied that fish can determine the direction and range of underwater sound at frequencies range of 100 Hz to 1000 Hz even background's noise is presented. Lovell *et al.* 2005 reported that the *statocyst* of *P. serratus* is sensitive to the motion of water particles displaced by low frequency sounds of 100 Hz to 3000 Hz, with a hearing acuity similar to that of a generalist fish. Meanwhile, Higgs *et al.* (2001) reported that there were no differences in auditory threshold, bandwidth, or best frequency for zebra fish.

The Risso's Dolphin followed perceived sound stimuli up to 1000 Hz with a second peak response at 500 Hz. A weighted modulation rate transfer function (MRTF) reflected that the animal followed a broad range of rates from 100 Hz to 1000 Hz, but beyond 1250 Hz hearing response of animal was simply an offset or onset by Mooney *et al.* (2006). In addition, amount of 12 hatchling through sub-adult turtles (*Lepidochelys kemp*, *Chelonia mydas*, *Caretta caretta*) shows that juvenile green turtles have a slightly broader hearing range of 100 Hz to 800 Hz with best sensitivity at 600 Hz to 700 Hz whereas sub-adults are ranging from 100 Hz to 500 Hz. Furthermore, *Kemp's* *Ridleys* had a more restricted ranging from 100 Hz to 500 Hz with most sensitive hearing of 100 Hz to 200 Hz as examined by Ketten *et al.* (2005).

Fish can hear a wide range of sounds, however there is a great variety of capabilities between species as studied by Lovell *et al.* (2005). The study also reported that both of the structures involved in sound reception and the abilities of hearing of the paddlefish and the lake sturgeon using a combination of physiological and morphological approaches revealed that both fish are responsive to sounds ranging in frequency from 100 Hz to 500 Hz. Moreover, the lowest hearing thresholds from both species were acquired from frequencies in a bandwidth of between 200 Hz and 300 Hz, with higher thresholds at 100 Hz and 500 Hz.

Howarth (2003) reported that the collective knowledge of sound detection and marine hearing capabilities is limited. Much of knowledge on the hearing frequencies of marine animals is based on the range frequency at which they vocalize rather than the range at which they actually hear. Furthermore, fishes, which has jurisdiction over most marine mammals and all sea turtles in the region, has not been set any standard measurement for their safe sound levels. Thus, this reason had caused limited knowledge of true hearing thresholds of such animals and their sensitivity to various sound levels especially of frequencies and durations.

Investigations into the hearing ability of marine fish have most often yielded results exhibiting a narrower hearing range and less sensitive hearing than its hearing specialist. This was first demonstrated in a variety of marine fish, and later other research demonstrated in taxonomically and ecologically diverse marine species reviews.

However, since the leopard sea robin has a swim bladder while the long spine bullhead does not, this illustrates the diversity of species in this order and makes extrapolation on hearing from two fish to all members of the group, which are very difficult to be identified. At the same time, considering potential sources that are in the mid and high-frequency range, a number of potential effects are clearly eliminated. Most significantly, since the vast majority of fish species studied to date are hearing generalists and cannot hear sounds above 500 Hz to 1500 Hz (depending upon the species), there are not likely to cause behavioral effects on these species from higher frequency

sounds. Moreover, even those marine species that may hear above 1500 Hz, such as a few sciaenids and the clupeids (and relatives), have relatively poor hearing above 1500 Hz as compared to their hearing sensitivity at lower frequencies. Thus, it is reasonable to suggest that even among the species that have hearing ranges that overlap with some mid and high frequency sounds, it is likely that the fish will only actually hear the sounds if the fish and source are very close to one another.

Furthermore, since the vast majority of sounds that are of biological relevance to fish are below 1000 Hz, even if a fish detects a mid or high frequency sound, these sounds will not mask the detection of lower frequency biologically relevant sounds. Thus, a reasonable conclusion, even without more data, is that there will be few and more likely no impacts on the behavior of fish. At the same time, it is possible that very intense mid and high frequency signals, and particularly explosives, could have a physical impact on fish, resulting in damage to the swim bladder and other organ systems. Even these kinds of effects had only been shown in a few cases in response to explosives; however only fish had been very close to the source affected.

Such effects have never been shown to any Navy sonar. Moreover, at greater distances there appears to be little or no impact on fish, and particularly no impact on fish that do not have a swim bladder or other air bubble that would be affected by rapid pressure changes.

III. Turtle auditory brainstem response (ABR)

Four difference ages of green turtles which are 2, 5, 9, and 30 years have been measured. The type of transmitted stimulus for ABR measurement is click stimulus. Observations focused on the right inner ear turtle since it represent the ABR of the object. In addition, Blackman filter has been deployed in the recording in order to reject the artifact. ABR waveforms on turtle have been successfully recorded. It was indicated by the ABR response in the time domain. Furthermore, recording signals were categorized into continuous signal (time domain) and converted signal in its spectral (frequency domain).

ABR consist of continuous waveform and then converted into its spectral. Typical ABR recordings contain certain peaks and valleys in the particular range. Furthermore, ABR response is commonly found between 1 to 15 ms from the time of stimulation. The spectral demonstrates the maximum magnitude occurred at 355.5 Hz. In addition, the time setting is varied every 100 μ s, while the time range is from 100 μ s to 2000 μ s. Most occurrences (15 stimulus durations) of peak power are about 300 to 500 Hz. Only two occurs occurred where the peak power of turtle response achieved above 1000 Hz. Turtle ages 2 years hearing ability is ranging from 50 to 1500 Hz which is obtained from the lowest to highest frequency in whole data while the average sensitivity is about 495.135 Hz. The hearing sensitivity of green turtle ages 30 mostly occurred ranging in 300 Hz to 500 Hz in 9 point stimulus of 15 data, even in 3 of 15

stimuli the sensitivity is achieved at frequency above 500 Hz. The analysis has resulted that the mean of hearing sensitivity is obtained at 534.887 Hz with standard deviation of 163.8. In addition, the hearing bandwidth for whole turtles is relatively narrow, from 75 to 1200 Hz, which is obtained from intersection frequency range. While the turtle sensitivity is ranging from 300 Hz to 500 Hz. ABR responses have been recorded and analyzed, where the ABR signal in the time domain has been transformed into the spectral form. Furthermore, each species has been summarized into its hearing ability.

For all ages of turtles, it can be summarized that turtle has the lowest hearing range of 5 Hz while the highest hearing is 1900 Hz. The details of hearing ability for each species are discussed as follows. Turtle age of 2 years response to sound with sensitivity at average of 495.135 Hz with ranging of 50 to 1500 Hz. Turtle ages of 5 years exhibits the response to stimulus on sensitivity at average 355.464 Hz with hearing ability is ranging from 5 to 1900 Hz. The significant result for hearing sensitivity of turtle ages of 9 years is average at 520.480 Hz. The entire range of frequencies is summarized from 5 to 1600 Hz. Meanwhile, hearing ability for turtle ages of 30 years is average 534.887Hz with hearing range of 10 to 1200 Hz. Hence, from the results of four turtle, the value of minimum frequency that occurs for each turtle can be found. Thus, from series of minimum frequency data, it could be plotted as in Figure 1. The figure shows that minimum frequency of turtles is plotted exponentially. Due to the exponentially results of the graph function, the curve fitting determined that the data accuracy is at R square: 0.9606.

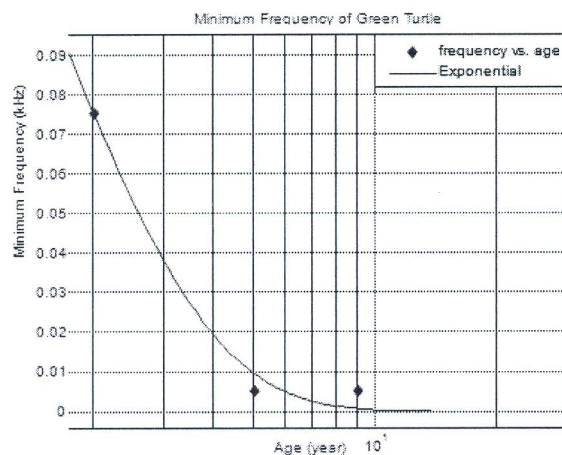


Figure 1. Minimum frequencies of turtles hearing

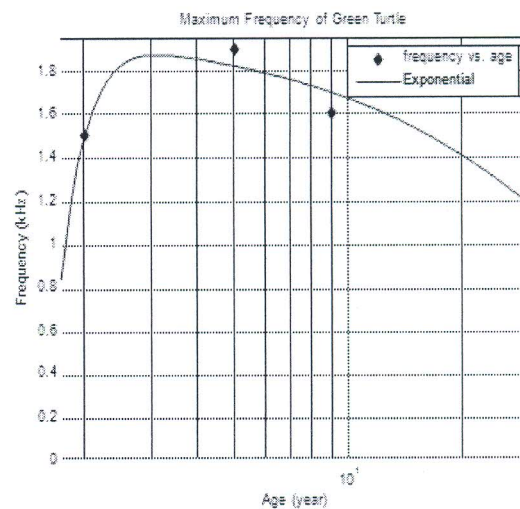


Figure 2. Maximum frequencies of turtles hearing

Similar to the minimum frequency function, the data series of maximum frequency for each turtle has been taken. The result is demonstrated in Figure 2.

The figure shows that maximum frequency of turtles plotted exponentially. Due to the exponentially results of the graph function, from the curve fitting determined that the data accuracy is at R-square: 0.9344.

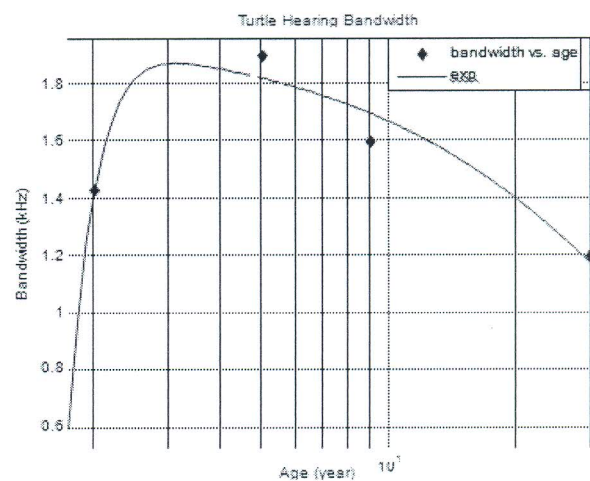


Figure 3. Green turtle's hearing bandwidth

In next calculation, the minimum and maximum frequency of data series has been expanded to obtain the hearing bandwidth for each turtle. Thus, bandwidth for each turtles is summarized at Figure 3 and hearing bandwidth of turtles is plotted exponentially. Due to the exponentially of graph function, the curve fitting has been obtained that data accuracy is at R-square: 0.9388. Finally, hearing range for each turtles can be displayed. The result show there is some intersection frequency between one turtles and others. The

summary of hearing range is plotted in one graph aim to determine the intersection zone. It is clear that intersection zone for all types are occurred at frequency ranging from 50 Hz to 1200 Hz.

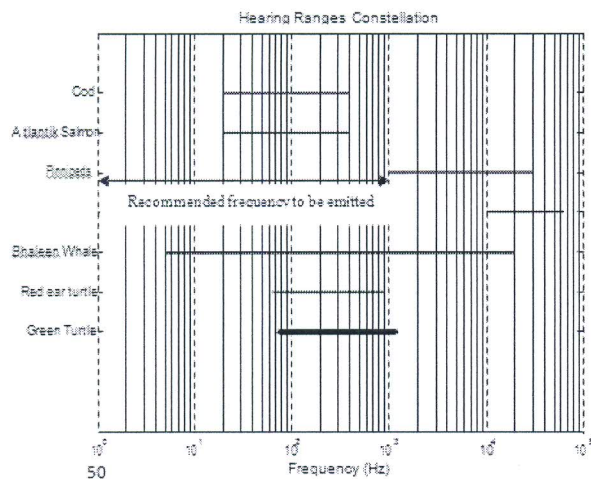


Figure 4. Hearing Range Constellation

The results of turtles hearing bandwidth have been plotted in one graph with other sea animal. The hearing ranges constellation green turtle compare to other sea animal can be seen in Figure 4. It is shown that hearing ranges of Green Turtle overlap with some frequency of cod fish, Atlantic salmon, Pinipeds, Thooted whale, and red ear turtle. However, this phenomenon is not occurring for all range of hearing.

IV. Sound characterization

The subsection augments the detail analysis of sound effects of behavioral response of turtles to underwater sound from generator. Using the hearing ability data from ABR analysis, sound source suitable with turtle hearing is emitted. In order to enrich the variety of the data, various sounds were adjusted. In this study, the sound types that have been emitted were LFM (Low and High Frequency Modulation), sinusoidal, and White Noise (WN) as provided by manufacturer. For this step of measurement, the speaker is located in the middle of the research tank meanwhile the hydrophone is placed at radius 1 m to 7 m of right and left side speaker respectively.

LFM sound recording for radius 1 m from speaker is depicted at Figure 5. Spectral signal has maximum magnitude at 166 Hz with SPL 140.9 dB re 1 Pa. There are harmonics about 500 Hz and above 800 Hz.

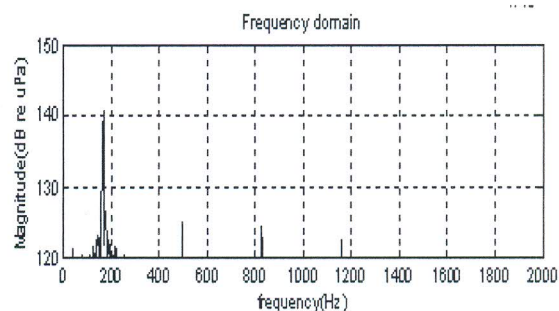


Figure 5. LFM spectral sound profiles

In similar method, the measurement is conducted up until 7 m radius of right side and left side from speaker respectively. Recording and sound analysis for LFM sound has been conducted. The results show that for all point of measurement, the average of peak power and RMS SPL occurred at 268.143 Hz and 98.983 dB re 1 Pa. Sinusoidal sound recording for radius 1 m from speaker is depicted at Figure 6. Meanwhile the spectral signal show that peak of power occurs at 356 Hz with SPL 137.4 dB re 1 Pa. There are harmonics about above 100 Hz, 1600 Hz and 1900 Hz.

In similar method, the measurement is conducted until radius 7 m right side and left side from speaker respectively. Recording and sound analysis for sinusoidal sound has been conducted. The results show that for all point of measurement the average of peak power and RMS SPL occurred at 314.53 Hz and 97.36 dB re 1 Pa.

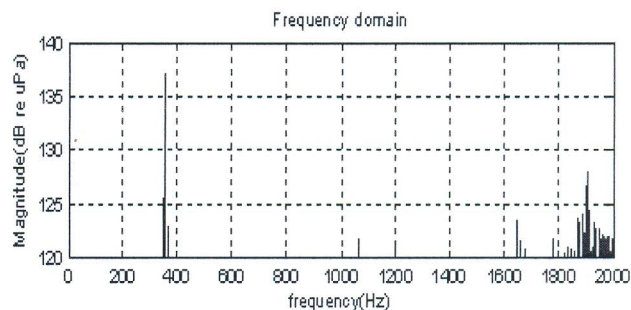


Figure 6. Spectral of sinusoidal sound profile

The next measurement is conducted to record white noise sound. This type of sound recording is monitored for radius 1 m from speaker as depicted at Figure 7. This signal has peak of power at 265 Hz with SPL 136.6 dB re 1 Pa, above 400 Hz, 600 Hz, 800 Hz, and 1300 Hz.

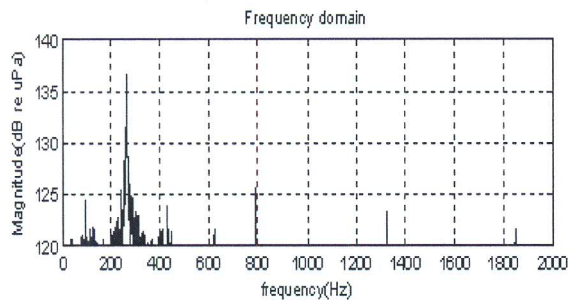


Figure 7. Spectral of White noise sound profiles

In similar method, the measurement is repeated for radius 2 to 7 m right side and left side from speaker respectively. Recording and sound analysis for WN sound has been conducted. The results show that for all point of measurement the average of peak power and RMS SPL occurred at 304.27 Hz and 112.99 dB re 1 μ Pa. Finally, sound propagation in the seawater in habitat and seawater in the research tank has been performed. A group of sound source has been monitored too. The research indicated that difference of measurement point did not affect sound profile especially for RMS magnitude and maximum magnitude value.

V. Turtle and Fish Response

Turtle and fish behavior towards sound is significant finding from in this study. The results of the observation to the species respond toward sound are basis knowledge for the future Turtle Excluder Device (TED) design. Observation of turtle response towards emitted sound carried on the main tank on the last measurement. There were two species have been observed which is turtle at the age of 30 years male and female. The types of emitted sound were LFM, sinusoidal, and WN. The result shows that turtle are behavioral avoidance for all types of emitted sound. Turtle more sensitive towards LFM and WN, whereas sinus sound was less. The female turtle response is slower than male turtle towards emitted sound. Turtle response measurement later has been conducted in the same tank and species. Advanced measurement was focused to determine the sensitivity of the turtle to emitted sound that depend on distance changing. Type of sound was LFM at low frequencies 300 Hz and 9000 Hz, while for the high frequency 1000 Hz is chosen. The modulation is adjusted at 500 Hz and the gain 10 dB.

Similar with previous method, turtle responses have been conducted. There were 7 turtles put into the tank. It is the combination of turtle ages above 7 years in male and female combination. Low frequency of LFM signal changed into 300 Hz. The research show that the male and female turtle excluded from the emitted sound. Changing of the distance between the turtle and the sound source has no effect on the turtle behavior. Monitoring of fish response towards emitted sound carried in the round small tank (radius: 2m) on the last measurement. Speaker located at the edge of the tank while hydrophone at the middle. Hydrophone was put in 40 cm

depth.

There were three species that have been observed which are *selar boops*, *selar papan*, and *selayang*. LFM, sinusoidal, and WN signals were emitted into the tank. LFM sound was emitted 2 channel where the combined frequency are 300 Hz and 600 Hz. Sinus signal is chosen in 300 Hz, 600 Hz, 900 Hz, and 1200 Hz. LFM is set up until volume level reach max 3. Fish gave no responses to all types of sound being emitted while the turtle behave likely to avoid the same emitted sound. Next monitoring of fish response towards emitted sound carried on the same tank. Speaker located at the edge of the tank while hydrophone at the middle. Location of hydrophone was changed to 20 cm depth. Total amount of fish put into the tank were 10 of different species. Later the behavior fish towards sound continued in the same manner for difference tank. The difference was in the number of fishes and tank deployed. The results show that fish didn't response towards all types of sound.

VI. Conclusion

Auditory Brainstem Response of turtles measurements have been conducted. The measurements conducted at a research tank by employing click and tone stimulus. The research focused on green turtle ages of 2, 5, 9, and 30 years. Fast Fourier Transform (FFT) has been applied to ABR responses of green turtle. As the results, the frequencies spectral of green turtles have been acquired. It has demonstrated that turtles hearing ability is relatively narrow in bandwidth ranging of (50-1200) Hz. Turtles and fish behavior towards sound has been observed. A group of sounds of different types that exclude green turtles have been determined. Also, the fish didn't response toward the same sounds. Finally, we have identified the sound specification to be deployed in the development TED without reducing the typical gill net performance. The future works will focus on implementing a TED prototype based on sound technique. Prior to the implementation of the prototype, the study of in situ sound propagation is also required. Also, in situ monitoring of turtle and fish behavior towards sound should be conducted. In addition, the prototype performance shall be evaluated by attaching it to the fishing gear.

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